



**AIAA Space 2000**



# **Internet Technology on Spacecraft**

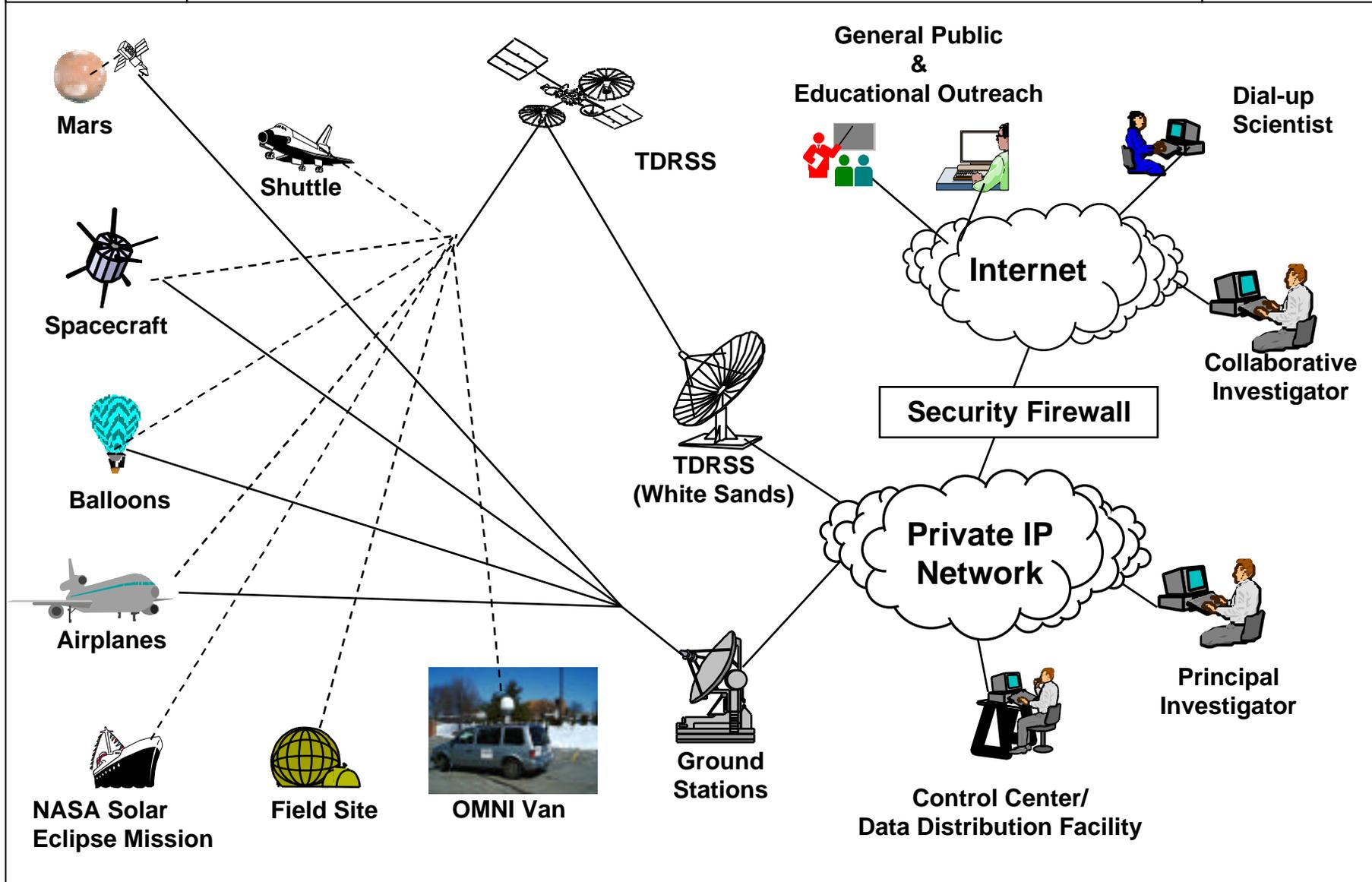
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**Computer Sciences Corporation**

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**NASA Goddard Space Flight Center**

**September 21, 2000**



# Space Internet Communication Concept





# Spacecraft Data Comm Challenges



## Spaceflight Issues

- **Continually intermittent links**
- **Highly asymmetric or unidirectional links.**
- **Maintaining a single address for a spacecraft as it uses different ground stations.**
- **Multiple mobile nodes forming a dynamic network topology.**

## Commercial Solutions

- **Mobile IP**
- **Mobile routing**
- **Cellular IP**
- **Dynamic Source Routing**
- **UDP based reliable file transfer.**



# Why IP on the Space Links?



## Where are the benefits?

- **Mission Design - Enables new multi-sensor missions (sensorweb), formation flying missions, collaboration between unrelated missions.**
- **Software development - Familiar sockets interface, testing with common network components.**
- **Testing and Integration - Remote testing with commercial networks and hardware. Testing with unmodified flight applications.**
- **Flight Operations - Use same S/W applications and H/W interfaces for flight ops as integration/test.**



# Security Issues

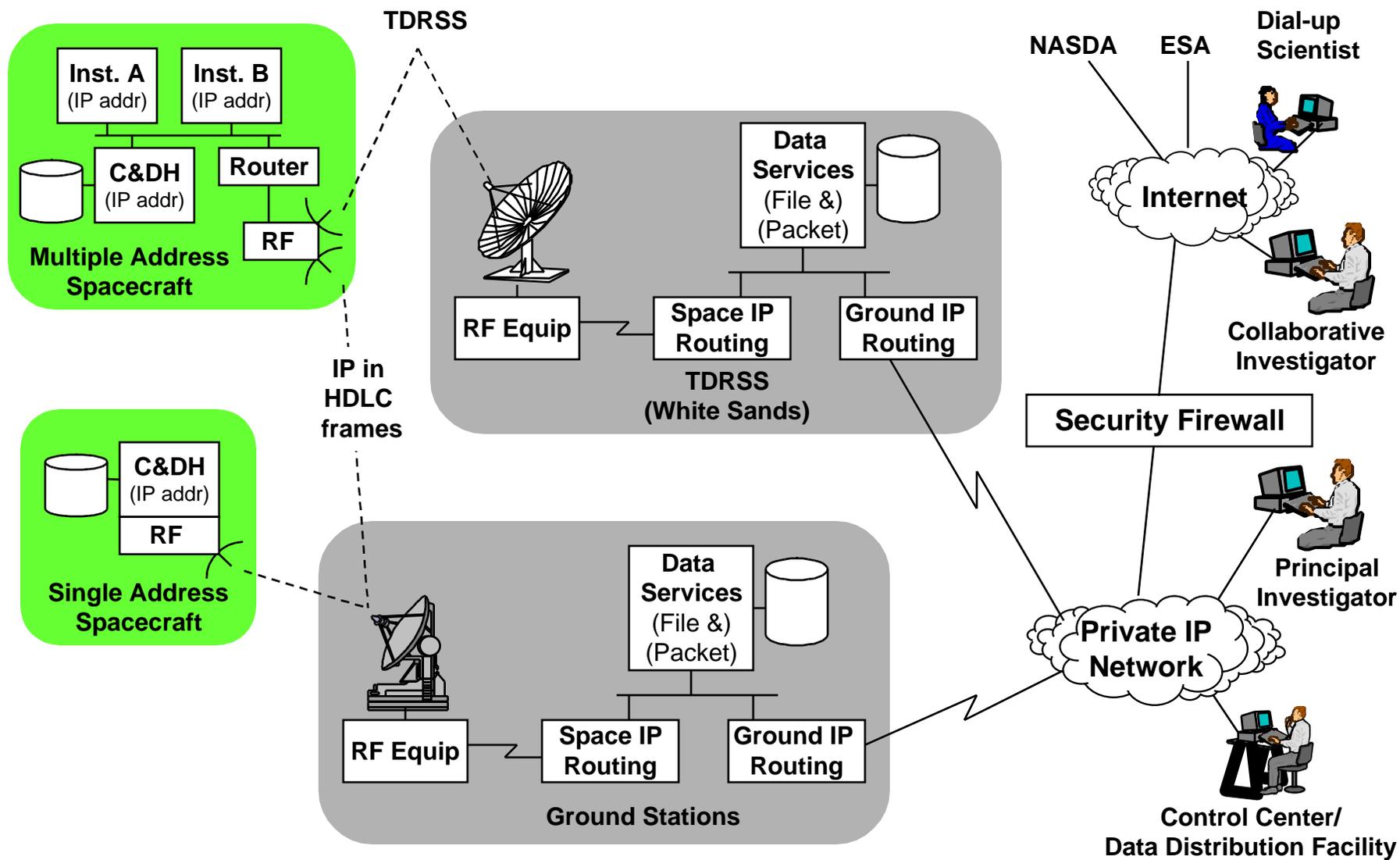


- **Authentication - Current Virtual Private Network (VPN) technology is readily available for most platforms.**
- **Encryption - Various encryption schemes such as Secure Socket Layer (SSL), Secure Shell (SSH) and many others are commercially available.**
- **Private Networks - The use of completely private networks provides the same security that has traditionally been used.**

**These solutions may be used individually or in any combination to meet the security needs of any mission for either uplink, downlink, or both.**



# Space Internet Implementation





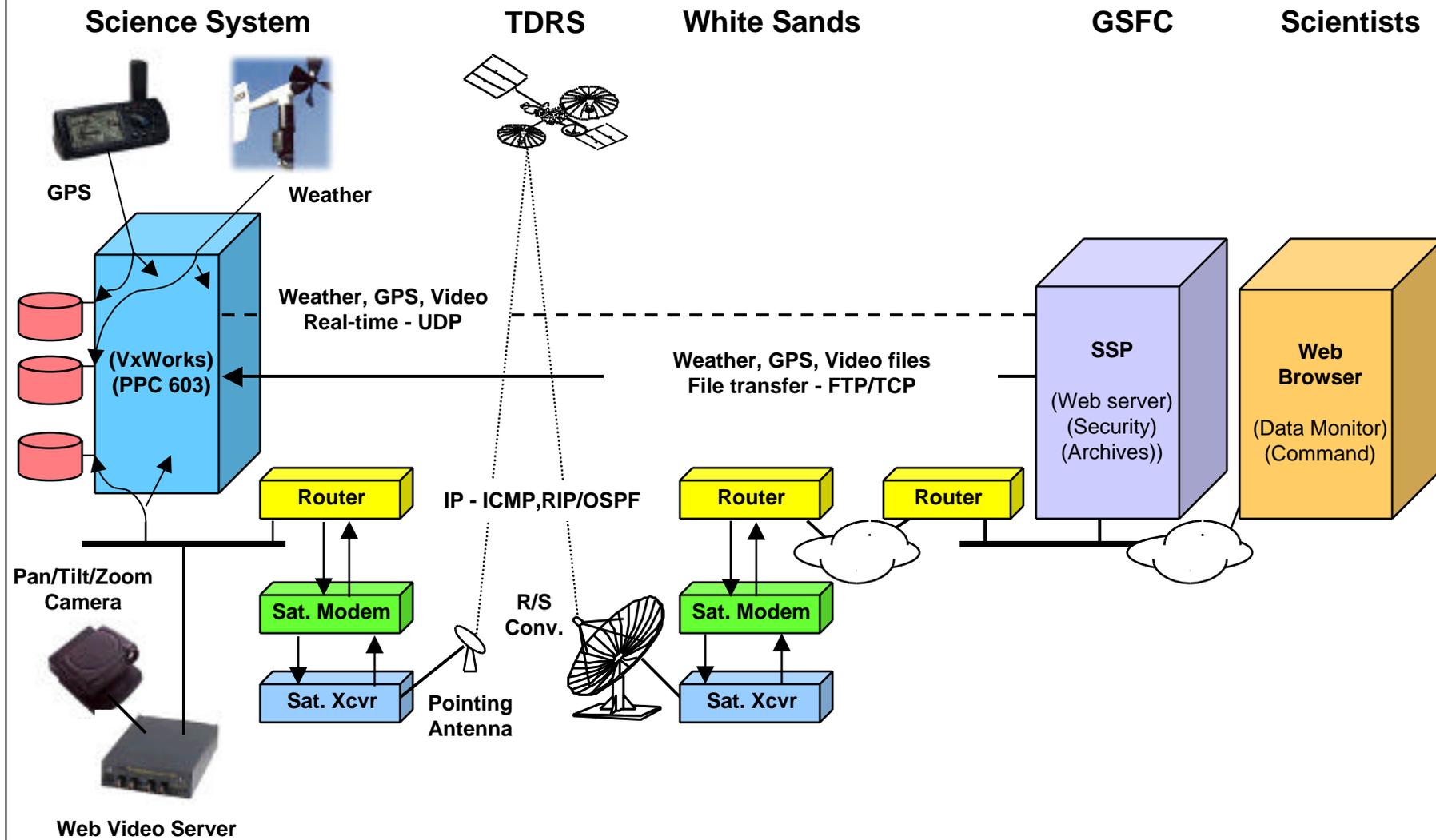
# OMNI Major Milestones



- **Feb-Apr 1999 - Demonstrations of IP communication through TDRSS to mobile spacecraft simulator (OMNI van)**
- **Aug 1999 - Solar eclipse mission in Black Sea - eclipse images and telemetry webcast via TDRSS to thousands of viewers**
- **Nov 1999 - JSC Inspection Day '99 - Supported Technology Showcase by providing live audio/video/telemetry from mobile OMNI van to the SOMO Technology Booth in the lobby of "mission control" in Houston.**
- **April 2000 - Began in-flight tests of basic IP connectivity and applications with Surrey Satellite Technology (SSTL) UoSAT-12 spacecraft.**



# End-to-End IP Communication Prototype





# IP Demo Prototype In Real Life

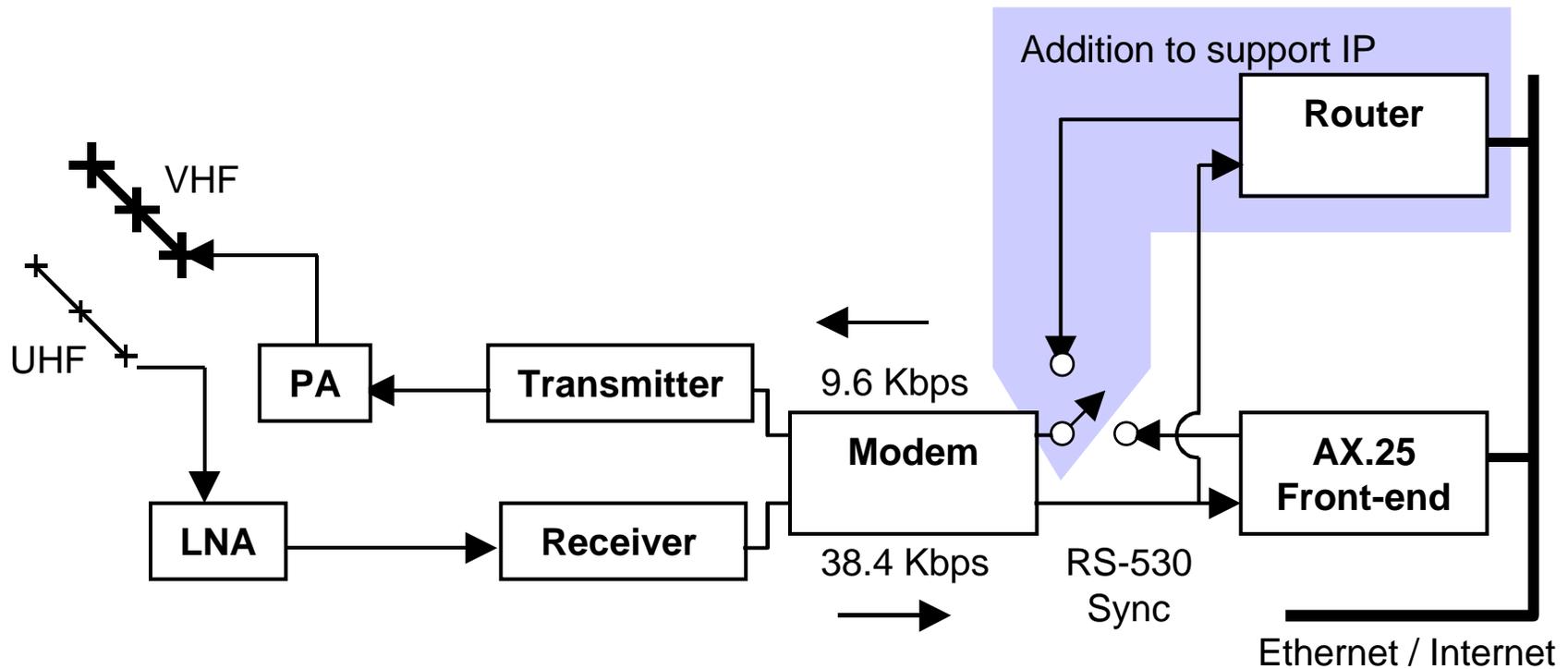




# UoSAT-12 IP Test Overview



- **UoSAT-12 and Surrey Ground Station Preparation**
- **Initial Tests (Phase I & II)**
  - Basic network connectivity (PING)
  - Spacecraft clock synchronization (NTP)
  - File transfer/link utilization (FTP)
- **Phase III and Beyond**
  - Real-time engineering data
  - Multicast data delivery
  - Unidirectional operations
    - Blind commanding
    - File transfer
  - Automatic store-and-forward (SMTP)
  - Multiple ground stations (Mobile IP)
  - Security (VPNs on ground and space links)





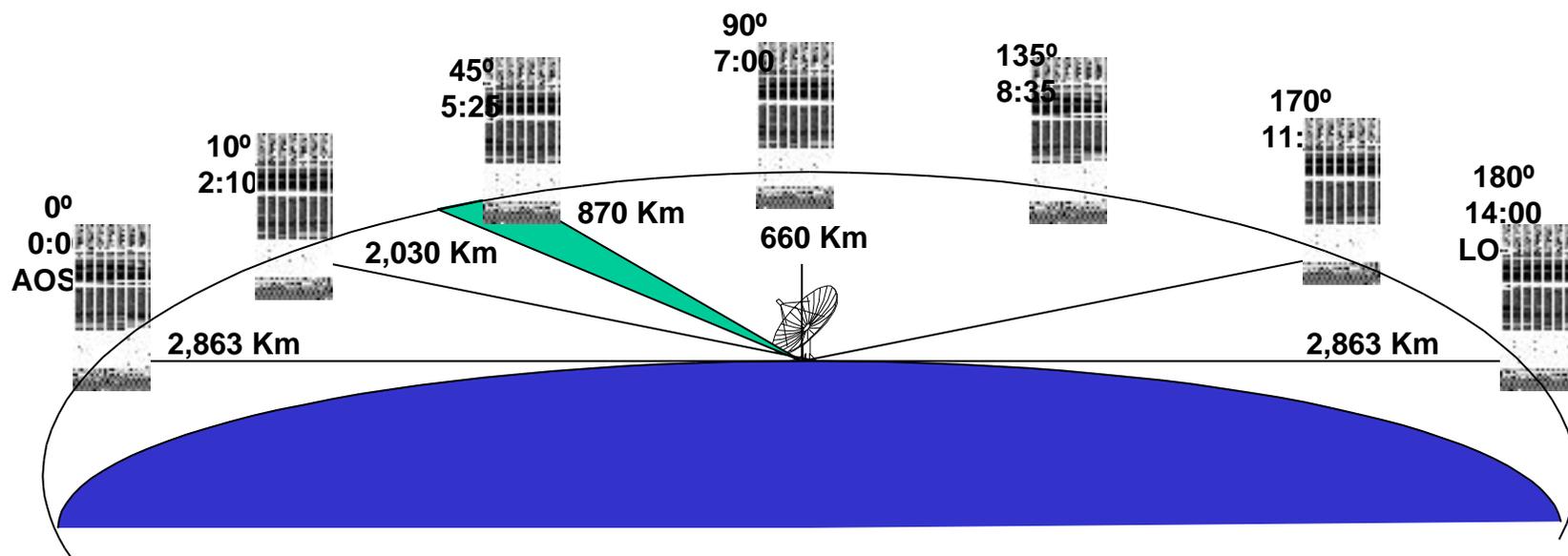
# UoSAT-12 Pass Characteristics



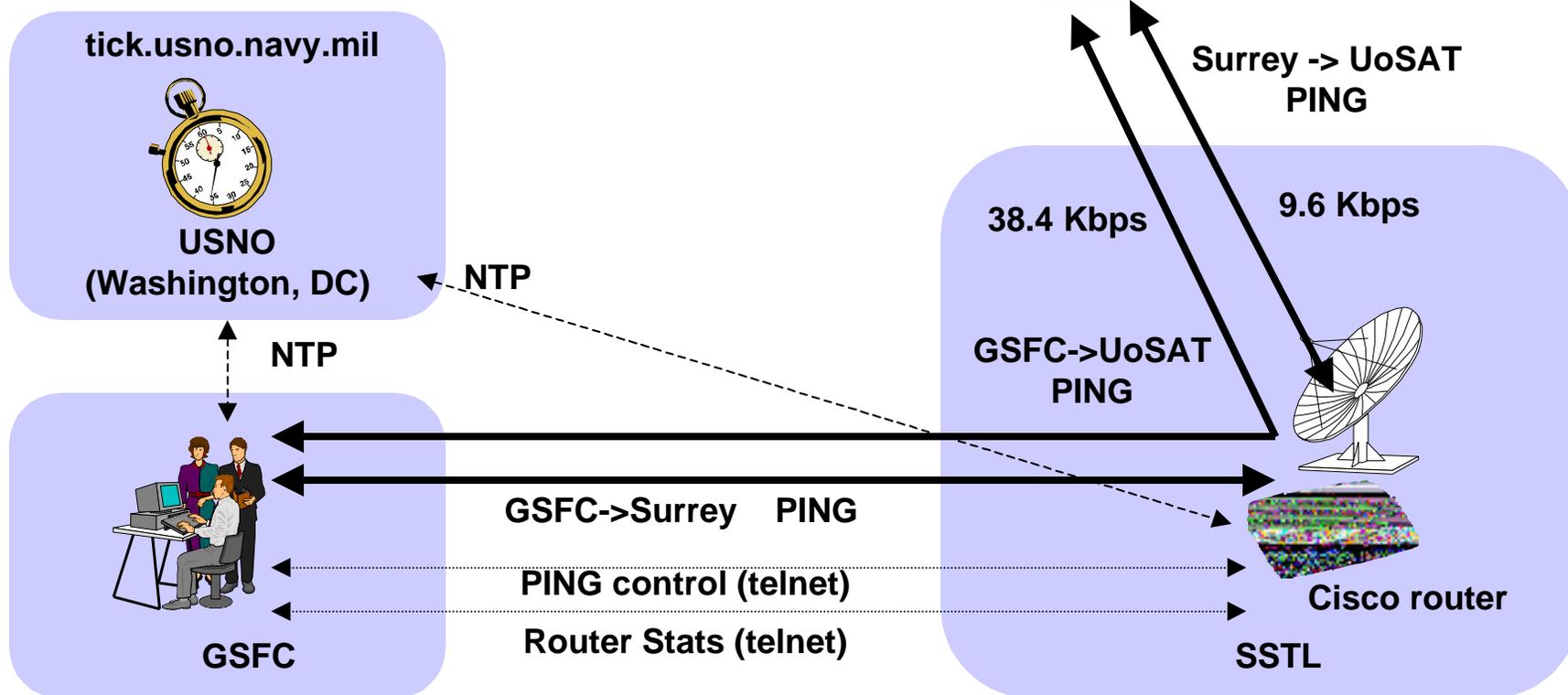
- Propagation delays are a function of data rate and distance

Pkt. Size \ Rate	9.6	38.4
64 byte (ms.)	53	13
1280 byte (ms.)	1,067	267

Data Path \ Elevation	0°	10°	45°	90°
One-way delay (ms.)	10	7	3	2
64B packet round-trip (ms.)	86	80	72	70
1280B packet round-trip (ms.)	1,354	1,348	1,340	1,338

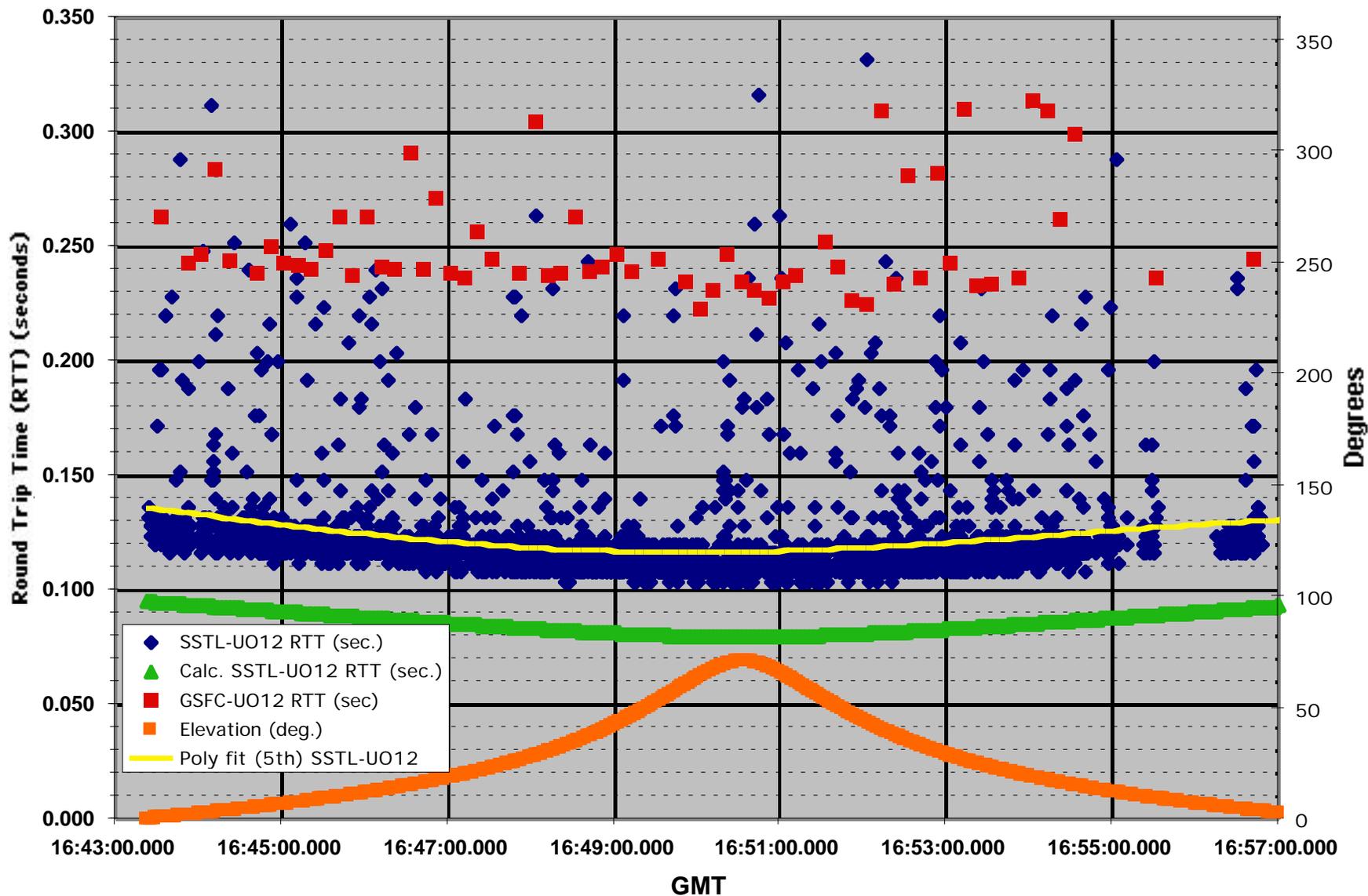


- Continual PING from router to UoSAT-12
- GSFC to Surrey router PINGs (10 sec.)
- GSFC to UoSAT-12 PINGs (10 sec.)
- Router monitoring from GSFC

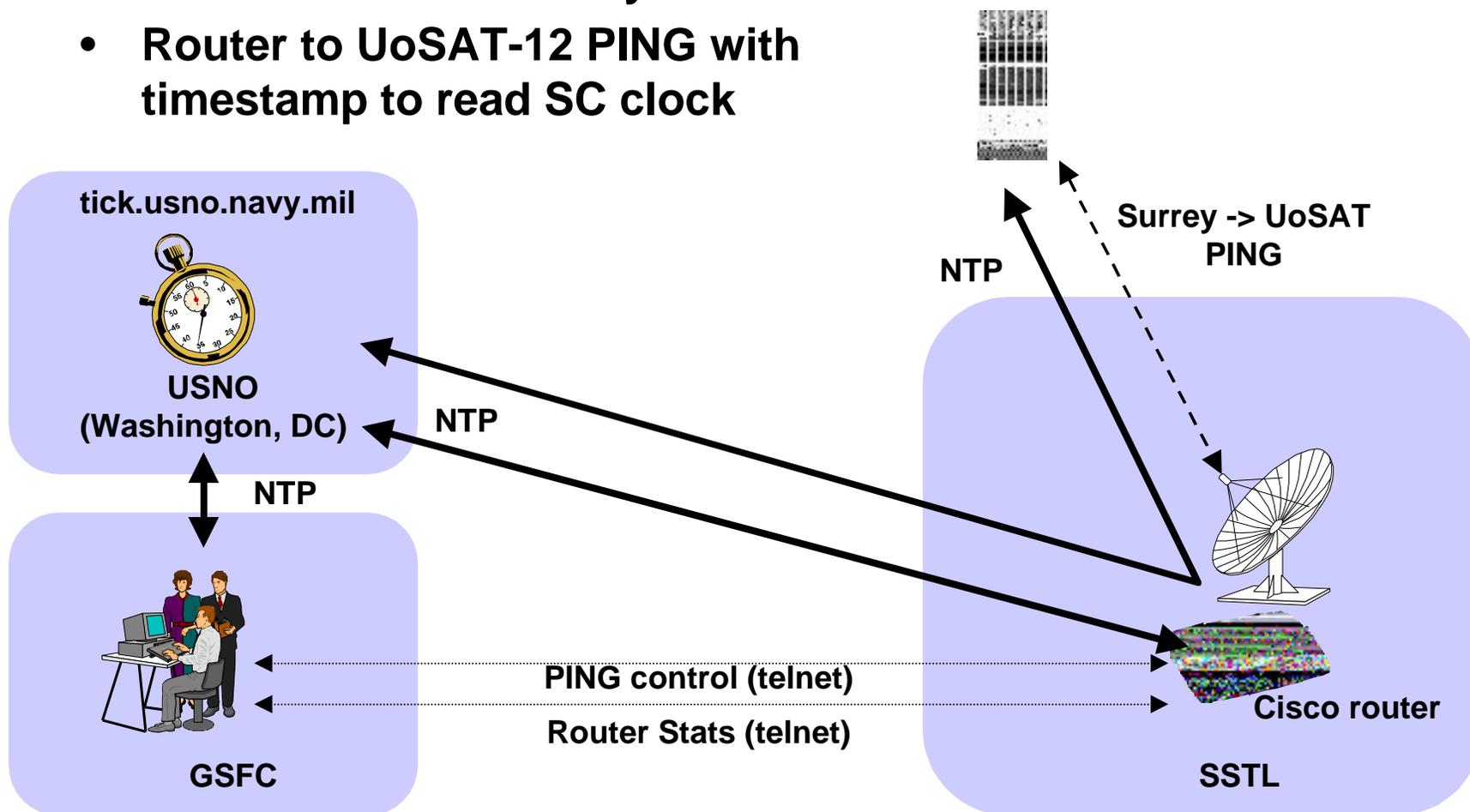




# PING Test 2 - 16:43 - Apr. 10, 2000

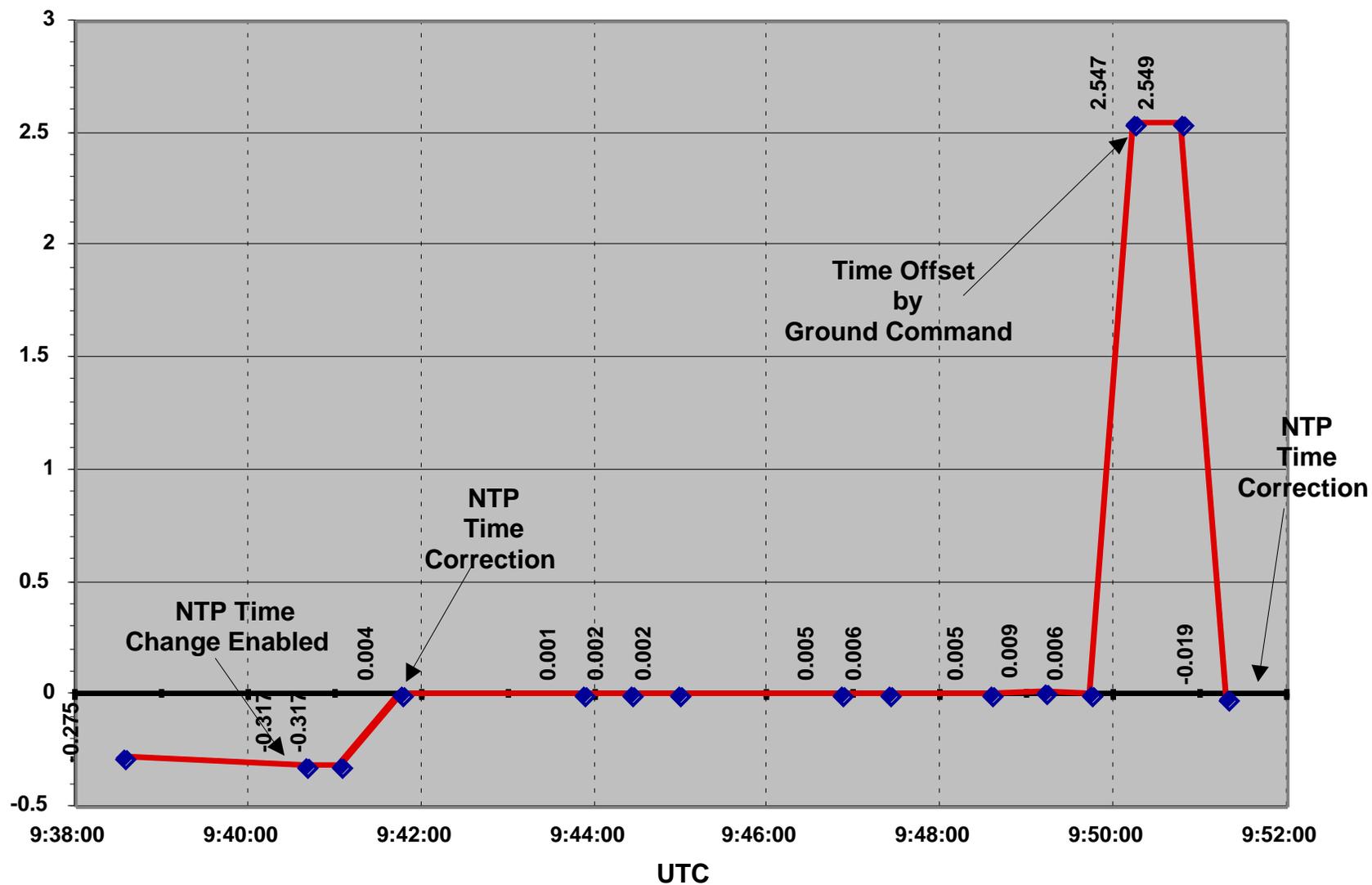


- NTP on UoSAT-12 to sync SC clock
- Router to UoSAT-12 PING with timestamp to read SC clock

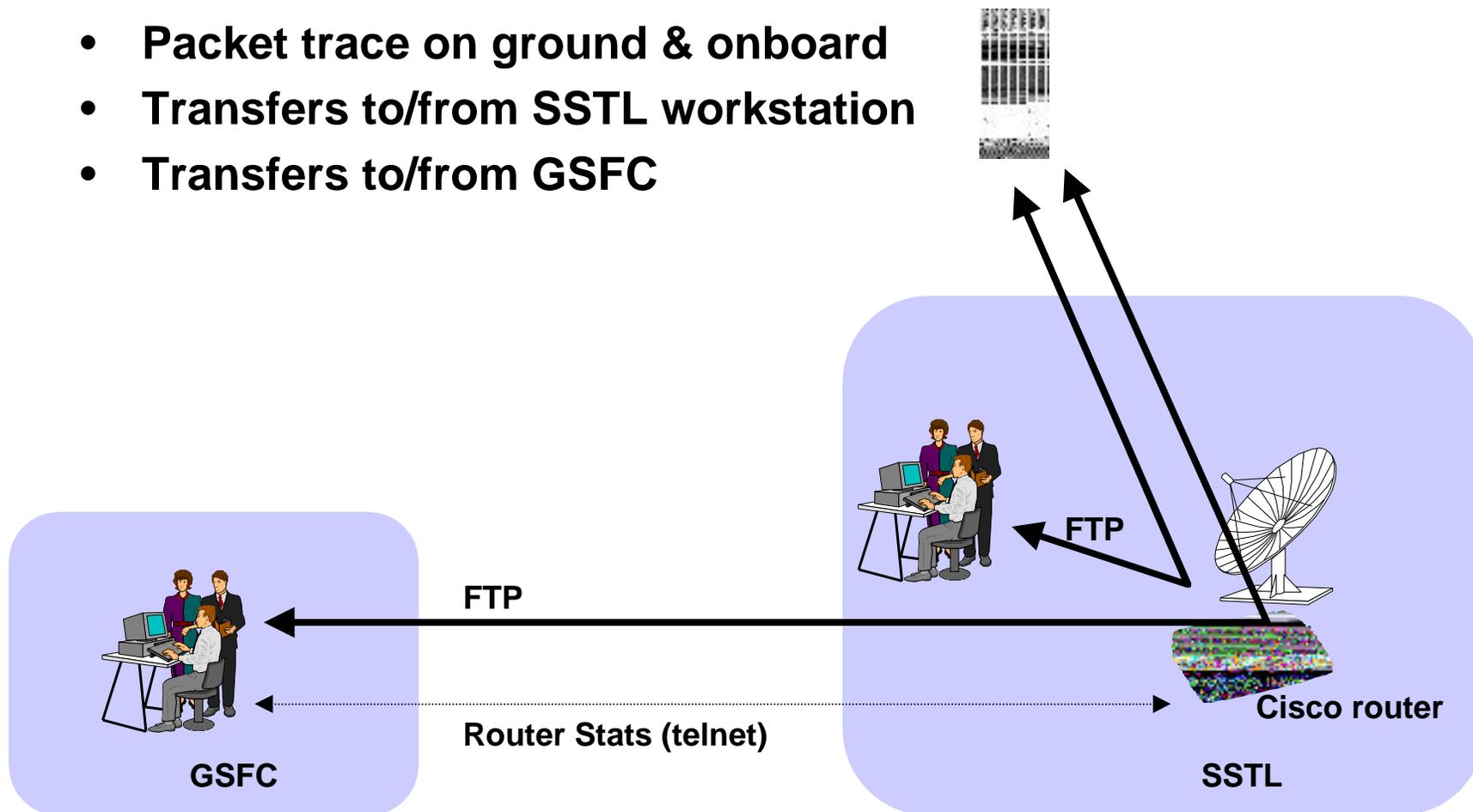




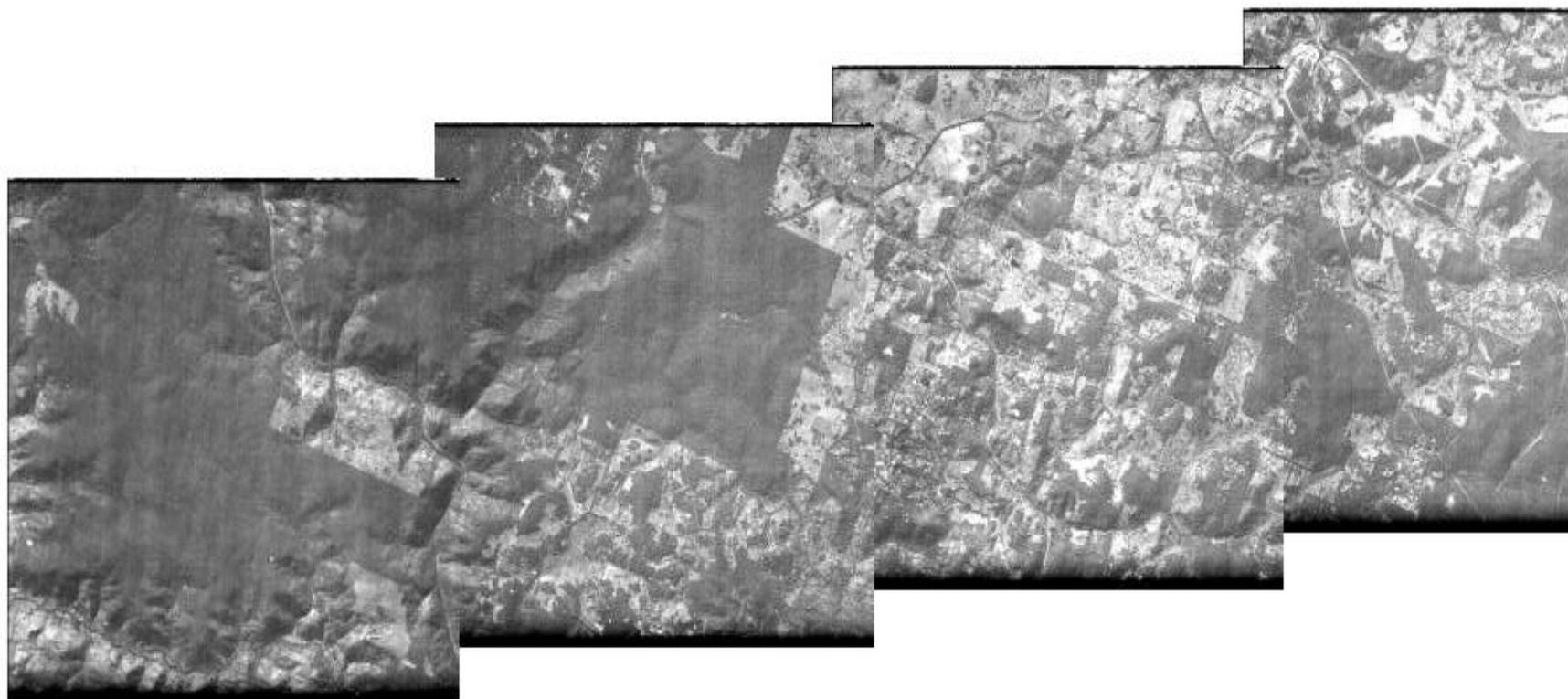
# NTP Test 1 - 09:38 - Apr. 14, 2000



- **FTP server on UoSAT-12**
- **Packet trace on ground & onboard**
- **Transfers to/from SSTL workstation**
- **Transfers to/from GSFC**



## Downloaded 4-Image Mosaic of Perth, Australia





- **Real-time data delivery (UDP)**
- **Reliable commanding (TCP) and blind commanding (UDP)**
- **File transport using HTTP**
- **Multicast real-time data delivery (UDP/IP multicast)**
- **Long delay path “reliable” file transfer (MFTP, CFDP, etc.)**
- **Automated file store and forward (SMTP)**
- **Automatic routing at multiple ground stations (Mobile IP)**
- **Network security (VPN at ground sites and spacecraft)**